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(54) Title of the Invention: **Electrophoretic Display Device and Production Method Thereof**

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SPECIFICATION

1. Title of the Invention

Electrophoretic Display Device and Production Method Thereof

2. Claims

(1) An electrophoretic display device, configured such that porous spacers are interposed between a group of mutually facing electrode plates, at least one of which is rendered transparent, and a disperse system containing dispersed electrophoretic particles is divided into discreet phases and sealed, said electrophoretic display device characterized in that one of the mutually facing electrode plates is rendered flexible, the other electrode plate is constructed from a transparent stiff body, and a hot-melt adhesive layer is disposed along the periphery of the porous spacers interposed between the two electrode plates.

(2) The electrophoretic display device according to claim (1), wherein the porous spacers are composed of an elastic member.

(3) The electrophoretic display device according to claim (1), wherein the porous spacers are composed of photosensitive film.

(4) The electrophoretic display device according to claims (1) to (3), wherein the hot-melt adhesive layer is a polyamide-based resin.

(5) A method for producing an electrophoretic display device, comprising the steps of preparing a transparent rigid electrode plate and a flexible electrode plate in which the required electrode patterns are formed on one side of a film member and a transparent glass plate; providing porous spacers disposed on the side of the rigid electrode plate facing the electrode pattern with an excess of a disperse system containing dispersed electrophoretic particles; disposing the flexible electrode plate on the porous spacers such that the electrode pattern thereof faces the electrode pattern of the rigid electrode plate; and applying heat and pressure to the upper surface of the flexible electrode plate to thermocompression-bond the flexible electrode plate and a hot-melt adhesive layer disposed along the periphery of the porous spacers while the excess disperse system is forced out, and to seal the disperse system in the holes of the porous spacers.

(6) The method for producing an electrophoretic display device according to claim (5), comprising the step of pre-bonding the rigid electrode plate and the porous spacers.

(7) The method for producing an electrophoretic display device according to claim (5) or (6), wherein the porous spacers are composed of an elastic body.

(8) The method for producing an electrophoretic display device according to claim (5) or (6), wherein the porous spacers are composed of photosensitive film.

(9) The method for producing an electrophoretic display device according to any of claims (5) to (8), wherein a polyamide-based resin is used for the hot-melt adhesive layer.

(10) The method for producing an electrophoretic display device according to any of claims (5) to (9), wherein the step for heating and bonding the flexible electrode plate to the porous spacers is performed sequentially with the aid of hot rollers from one end of the flexible electrode plate.

3. Detailed Description of the Invention

(Field of Industrial Utilization)

The present invention relates to a display device in which electrophoretic particles are used, and more particularly to a dispersion-type divided electrophoretic display device configured such that a flexible electrode plate composed of a resin film or the like is used in such an electrophoretic display device, as is a porous spacer designed to divide a display disperse system into discreet phases at narrow intervals, whereby the disperse system can be readily and securely sealed in the holes of the porous spacer, and also relates to a production method thereof.

(Prior Art and Problems Thereof)

An electrophoretic display device in which electrophoretic particles are used is configured such that two transparent glass plates 1 and 3 (on which the required display electrode patterns 2 and 4 are formed using indium/tin oxide or another appropriate transparent electroconductive member) are mounted on surfaces disposed opposite each other, and sealing members 5 designed to seal a disperse system 7 (obtained by dispersing electrophoretic particles 6 in a liquid dispersion medium) and provided with a spacing function are mounted at external peripheral locations, as shown in Fig. 3.

In such an electrophoretic display device, a display drive voltage is applied to the electrode patterns 2 and 4, an electric field is generated in the disperse system 7 such that the electrophoretic particles 6 are attracted or repulsed by the electrode patterns 2 and 4, and the distribution of the electrophoretic particles 6 is varied, whereby the optical characteristics of the disperse system 7 are changed, and the desired display actions is performed to form characters, symbols, diagrams, or the like.

When the disperse system 7 is sealed such that a continuous phase is formed by the sealing members 5 provided to the end portions in the above-described manner, the nonuniform electric field strength resulting from space nonuniformity or other factors affecting the relation between the two electrode patterns 2 and 4 cause the electrophoretic particles 6 to move parallel to the surface of electrode patterns and create nonuniformity in the concentration distribution of the electrophoretic particles, with the result that when the electrophoretic display device is repeatedly used for a long time, the concentration of the electrophoretic particles becomes different at different locations, and display nonuniformities form.

In view of this, means aimed at overcoming these shortcomings have been developed in the form of structures in which the disperse system 7 is divided and sealed as discreet phases at narrow intervals by sealing the disperse system inside through-holes with the aid of porous spacers 8 provided with a large numbers of such holes, as shown in Fig. 4. These structures are described in JP (Kokai) 49-32038, 59-34518, and 59-171930.

A dispersion-type divided electrophoretic display device in which a display disperse system is divided into discreet phases at narrow intervals with the aid of porous spacers still presents numerous obstacles in terms of obtaining a reliable display device because devising a cell structure in which two electrode plates and the interposed porous spacers are bonded in advance makes it difficult to uniformly pour a disperse system into the holes of a porous spacer, areas are created in which the disperse system has been poured nonuniformly, and the product becomes prone to the formation of display defects.

(Means Used to Solve the Above-Mentioned Problems)

The present invention provides a dispersion-type divided electrophoretic display device featuring porous spacers, wherein this electrophoretic display device is such that a disperse system can be readily injected into the holes of porous spacers in a reliable manner by providing a hot-melt adhesive layer that can be bonded by heat and pressure at prescribed locations on the porous spacers, and fashioning one of the electrode plates into a flexible structure.

For this reason, the electrophoretic display device of the present invention is configured such that a disperse system containing dispersed electrophoretic particles is divided into discreet phases and sealed via porous spacers between a group of mutually facing electrode plates at least one of which is rendered transparent, the electrophoretic display device being obtained by a method in which one of the mutually facing electrode plates is rendered flexible, the other electrode plate is configured from a stiff body, and a hot-melt adhesive layer, preferably composed of a polyamide-based resin, is disposed along the periphery of the porous spacers interposed between the two electrode plates.

The porous spacers used herein can be fabricated using elastic members or photosensitive film.

To produce such an electrophoretic display device, it is possible to adopt the steps of preparing a transparent rigid electrode plate and a flexible electrode plate in which the required electrode patterns are formed on one side of a film member and a transparent glass plate; providing porous spacers configured as described above and disposed on the side of the rigid

electrode plate facing the electrode pattern with an excess of a disperse system containing dispersed electrophoretic particles; disposing the flexible electrode plate on the porous spacers such that the electrode pattern thereof faces the electrode pattern of the rigid electrode plate; and applying heat and pressure to the upper surface of the flexible electrode plate to sequentially or otherwise thermocompression-bond (with the aid of hot rollers or the like) the flexible electrode plate and a hot-melt adhesive layer preferably composed of a polyamide-based resin and disposed along the periphery of the porous spacers while the excess disperse system is forced out, and to seal the disperse system in the holes of the porous spacers.

This technique allows a disperse system to be rapidly injected and sealed in a reliable manner inside the holes of porous spacers used in a display device in which the disperse system is contained in divided form.

(Working Examples)

The present invention will now be described in further detail with reference to illustrated working examples. In Fig. 1, 1 is a transparent glass plate used as a base for creating a transparent rigid electrode plate, and a desired electrode pattern 2 is appropriately formed on the upper surface thereof from indium/tin oxide or another transparent electroconductive material. Porous spacers 8 designed to divide the disperse system and seal it at narrow intervals are disposed on the upper surface of the rigid electrode plate, and a flexible electrode plate composed of a base 10 (in which another electrode pattern 4 is formed on a surface disposed opposite the electrode pattern 2 on the rigid side) is mounted at a specific distance on the upper surfaces of the porous spacers 8. The flexible electrode plate is used to apply a thermocompression bonding force (see below) through the upper surface of the flexible electrode plate to the disperse system 7 fed in excess into the holes of the porous spacers 8, and to gradually force out the excess disperse system 7 while bonding the plate with the spacers 8. Another function is to completely seal the disperse system 7 in the holes of the porous spacers 8 without leaving any empty holes by bonding the flexible electrode plate and the spacers 8 along the peripheries thereof under heat and pressure, providing an appropriate means for dividing and sealing the disperse system 7 and sealing the spaces between the structural members in a simple and prompt manner.

To bond the porous spacers 8 with the flexible electrode plate in the above-described manner, it is preferable that a hot-melt adhesive layer 9 composed of polyamide resin be placed in the peripheral area shown by hatching in Fig. 2. The hot-melt adhesive layer 9 may, for example, be a hot-melt adhesive sheet member such as PA-50 manufactured by Diabond

Industrial. The porous spacers 8 can be formed by a variety of techniques, such as preparing an elastic sheet material composed of synthetic resin (silicone resin, urethane resin, fluororesin, acrylic resin, or the like), natural resin, or other material; providing the sheet material with a large number of the required through holes 8A by punching, laser irradiation, or another appropriate means; and affixing the resulting sheet material to the rigid electrode plate on the side facing the electrode pattern 2. Alternatively, the spacers can be directly formed in monolithic manner on the side facing the electrode pattern 2 by printing the elastic member, or a photosensitive resin may be formed and bonded in the required thickness on the side facing the electrode pattern 2, and the through holes 8A may then be formed by etching or another chemical dissolution means.

In addition to titanium oxide and other conventional colloid particles, it is possible to use various organic and inorganic pigments and dyes, ceramics, resins, and other fine powders in an appropriate manner as the electrophoretic particles employed in the disperse system 7. In addition, hydrocarbons, halogenated hydrocarbons, aromatic hydrocarbons, other natural or synthetic oils, and the like can be arbitrarily used for the dispersion medium of the disperse system 7. Dispersants, lubricants, stabilizers, and the like can be appropriately added to the disperse system 7 as needed besides the charge-controlling agents composed of electrolytes, surfactants, metal soaps, resins, rubbers, oils, waxes, compounds, and other particles. The charge of the electrophoretic particles can be made uniform (positive or negative) to increase the zeta potential. Other appropriate means include adjusting the extent to which the electrophoretic particles can be adsorbed on the electrode patterns 2 and 4, adjusting the viscosity of the dispersion medium, or the like.

To fabricate such a dispersion-type divided electrophoretic display device, a disperse system 7 (prepared in advance by dispersing titanium oxide or another type of electrophoretic particles in an appropriate liquid dispersion medium ideally suited to display purposes) is fed in excess to the porous spacers 8 configured as described above and disposed on the rigid electrode plate (comprising a transparent glass plate 1 and a transparent electrode pattern 2) on the side facing the electrode pattern 2 such that the amount of the disperse system is equal to or greater than the amount required for the porous spacers 8, and the spacers 8 are completely covered by the disperse system 7.

The required display disperse system 7 is produced in advance by a method in which hexyl benzene (100 cc) is prepared as a dispersion medium, a dark-blue dye (1 g) composed of Oil Blue BA and a surfactant (0.5 g) consisting of Sylvan S83 are dissolved therein, and titanium oxide (5 g) is dispersed as electrophoretic particles in the solvent.

Heat and pressure are then applied using heated rollers or the like to the upper surface of a flexible electrode plate, and a sealing treatment is sequentially performed from one end thereof in a state in which the flexible electrode plate is superposed on the porous spacers 8 such that the electrode pattern 4 thereof faces the electrode pattern 2 of the rigid electrode plate in the manner shown in Fig. 1, whereupon the flexible electrode plate is adequately pressed against the porous spacers 8 and is thermocompression-bonded to the hot-melt adhesive layer 9 on the periphery thereof. The excess disperse system fed to the through holes 8A of the porous spacers 8 is forced out of the holes in the spacers 8, and the disperse system 7 is thus sealed in an appropriate manner. A divided disperse system devoid of empty holes can thus be completely sealed in the porous spacers 8, and the members can be bonded to each other, with the two types of treatment performed in a simple and prompt manner.

A dc voltage of 70 V was repeatedly applied between the electrode plates of the electrophoretic display device thus fabricated, and switching tests were performed. The tests demonstrated that the electrophoretic particles remained uniform after 1,000,000 switching cycles and that a display operation having adequate contrast could be maintained.

(Merits of the Invention)

The electrophoretic display device pertaining to the present invention is an electrophoretic display device in which porous spacers are used to divide a disperse system into discreet phases at narrow intervals and to seal the system between electrode plates, wherein one of the two electrode plates is fashioned into a flexible body, the other is fashioned into a rigid body, and porous spacers capable of being thermocompression-bonded in peripheral areas are interposed between these two electrode plates, so excess disperse system is forced out and securely sealed in the holes of the porous spacers while the porous spacers and the flexible electrode plate are bonded to each other under heat and pressure by a process in which heat and pressure are sequentially applied to the side facing the flexible electrode plate in a state in which the flexible electrode plate is mounted on the thermocompression-bondable porous spacers provided with an excess of the display disperse system, making it possible to divide and seal the disperse system without any empty holes in a secure operation that is efficient, has a short duration, and is easy to accomplish.

It is therefore possible to provide an excellent dispersion-type divided electrophoretic display device that is devoid of display defects, has good contrast, and possesses high display reliability by adopting the electrophoretic display device according to the present invention, as well as a production method thereof.

4. Brief Description of the Drawings

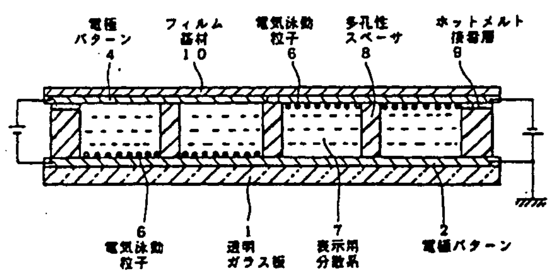
Fig. 1 is a schematic enlarged cross-sectional view of a dispersion-type divided electrophoretic display device configured such that porous spacers that can be bonded under heat and pressure are interposed between a transparent rigid electrode plate and a flexible electrode plate in accordance with a working example of the present invention;

Fig. 2 is a fragmentary plan view illustrating a state in which a hot-melt adhesive layer is disposed along the periphery of the porous spacers in order to make it easier to bond the porous spacers and the flexible electrode plate by the technique of the present invention;

Fig. 3 is a schematic cross-sectional view of a dispersion-type, continuous-phase electrophoretic display device provided with a conventional structure devoid of porous spacers; and

Fig. 4 is a schematic cross-sectional block diagram of a dispersion-type, continuous-phase electrophoretic display device fashioned according to a conventional structure provided with porous spacers.

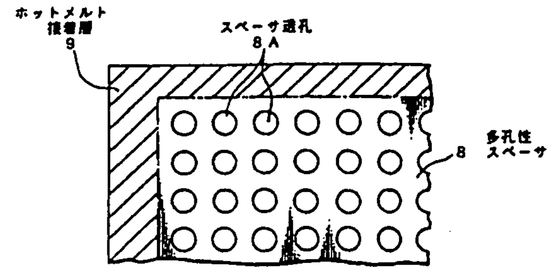
1: transparent glass plate, 2: electrode pattern, 3: transparent glass plate, 4: electrode pattern, 5: end spacer, 6: electrophoretic particle, 7: display disperse system, 8: porous spacer, 8A: through hole in spacer, 9: hot-melt adhesive layer, 10: film base



第 1 図

Fig. 1

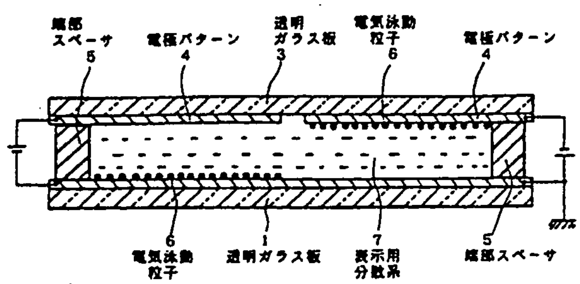
<u>Key</u> 4: electrode pattern, 10: film base, 6: electrophoretic particle, 8: transparent spacer, 9: hot-melt adhesive layer, 1: transparent glass plate, 7: display disperse system, 2: electrode pattern



第 2 図

Fig. 2

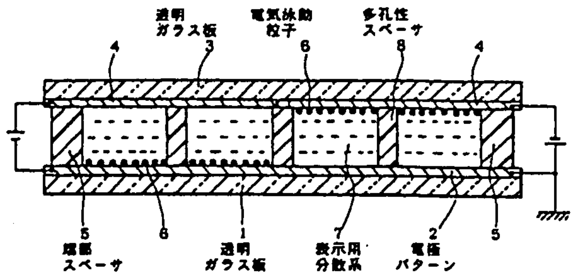
Key 9: hot-melt adhesive layer, 8A: through hole in spacer, 8: porous spacer



第 3 図

Fig. 3

Key 5: end spacer, 4: electrode pattern, 3: transparent glass plate, 6: electrophoretic particle, 4: electrode pattern, 1: transparent glass plate, 7: display disperse system



第 4 図

Fig. 4

<u>Key</u> 3: transparent glass plate, 6: electrophoretic particle, 8: porous spacer, 5: end spacer, 1: transparent glass plate, 7: display disperse system, 2: electrode pattern

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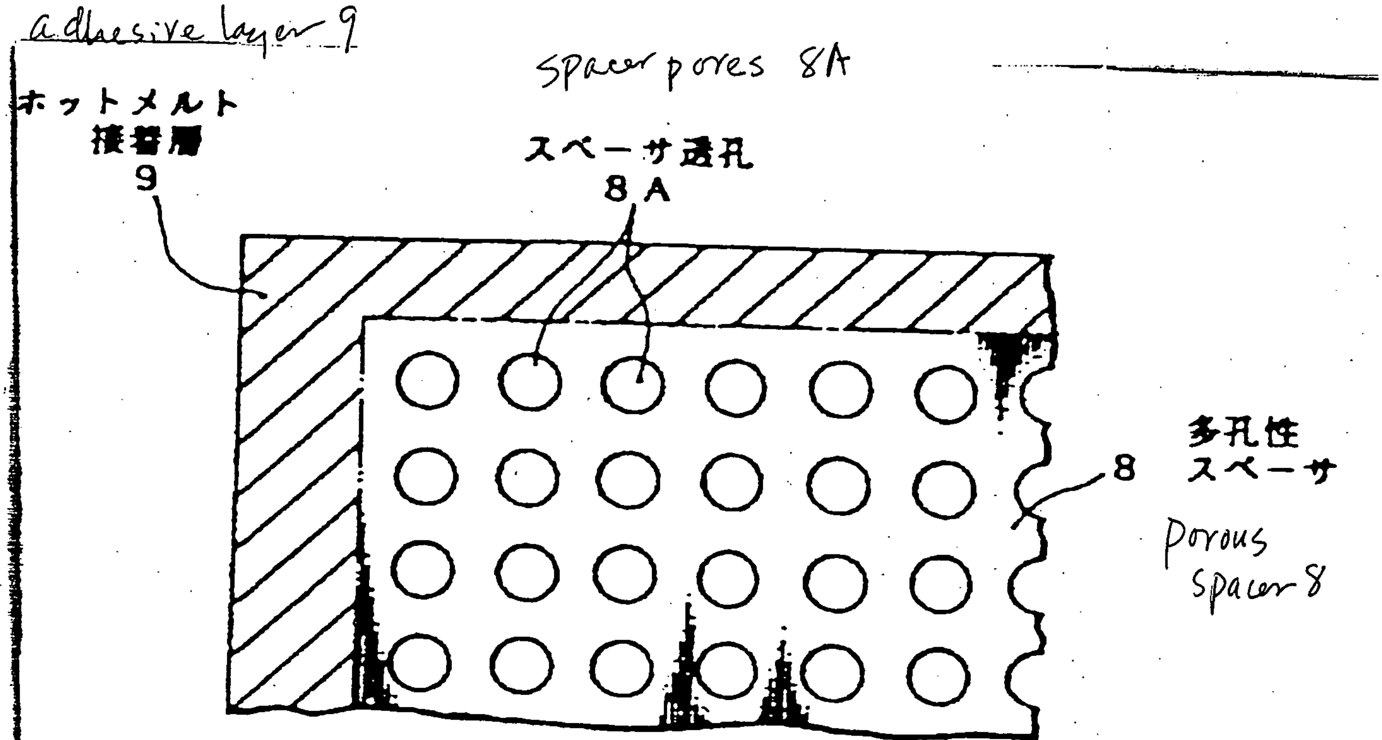

第 2 図

Figure 2

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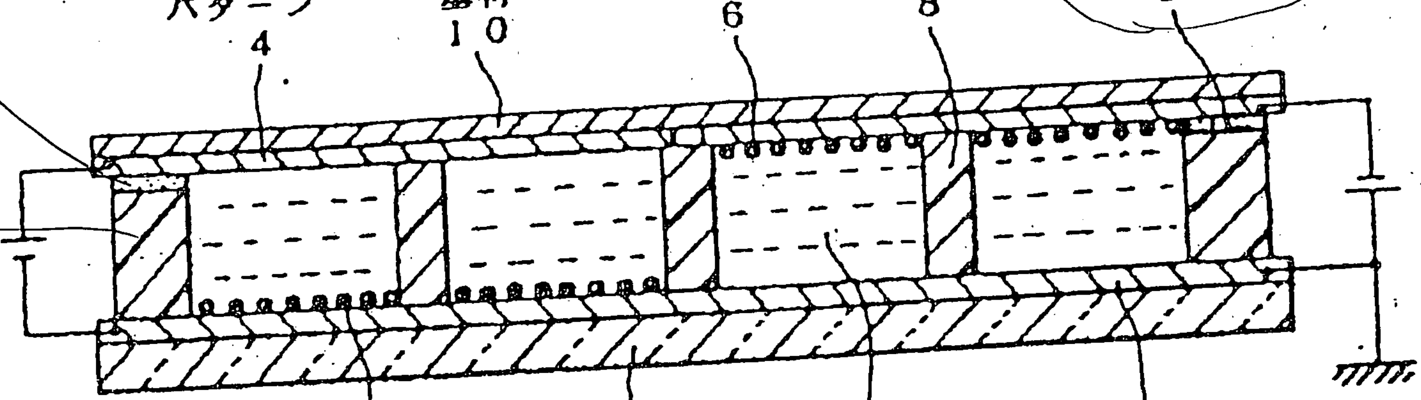
Figure 1



第 1 図